APPENDIX G-2

Oceanographic Data Collection and Evaluation: Phase 1 Status Report

Prepared for

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Long Island Sound Dredged Material Disposal EIS

Oceanographic Data Collection and Evaluation Phase I Status Report

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1.0 INTRODUCTION

The US Environmental Protection Agency (USEPA) and the United States Army Corps of Engineers, New England District (CENAE) are involved in the preparation of an Environmental Impact Statement (EIS) that will consider the potential designation of one or more dredged material disposal sites in Long Island Sound (LIS). To characterize the existing environment ENSR assessed existing hydrodynamic data in LIS to support evaluation of alternative open water disposal sites as part of the EIS. The hydrodynamics of Long Island Sound are an important component of the EIS process because the extent of dredged material transport in the open water environment is dependent on hydrodynamics. Specifically, ambient water currents can transport dredged material suspended in the water column during disposal events and can re-suspend and transport dredged material from the sea-floor via scouring following disposal events. Determination of the extent of dredged material transport in the open water environment is a critical component of the EIS process.

Federal regulations specify that a set of criteria be applied to support evaluation and potential designation of open water disposal sites (40 CFR Section 228.4(e), 228.5, and 228.6). These criteria include evaluation of physical, chemical, and biological characteristics, existing uses, and existing regulations at the site. In terms of hydrodynamic characteristics, the criteria specify that designated sites should afford minimal transport of dredged material away from the disposal site and that adjacent areas (e.g., fisheries and shorelines) should not be impacted. Evaluation of the potential for “dispersal, horizontal transport and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any” (Section 228.6 specific criteria #7) is specifically required as part of the site assessment process. Assessment of near-bottom currents are of critical importance in evaluation of potential disposal sites due to the potential adverse effects of re-suspension and transport of dredged material from the sea-floor. The EIS hydrodynamic assessment will be designed and conducted to satisfy applicable regulatory requirements.

The EIS hydrodynamic assessment task will result in a Sound-wide hydrodynamic characterization and a set of detailed, site-specific hydrodynamic characterizations at selected locations. The Sound-wide hydrodynamic characterization will support evaluation of potentially suitable areas for open water disposal site designation throughout the Sound. Detailed, site-specific hydrodynamic characterizations will support evaluation of alternative sites in terms of hydrodynamic suitability. For example, water velocity measurements collected at alternative open water disposal sites will be compared to support selection of appropriate disposal sites for designation. Site-specific hydrodynamic characterizations will include evaluation of the extent of potential dredged material transport (e.g., near-field water column mixing and transport predictions) at identified alternative disposal sites. Sufficient data are required to support each of these hydrodynamic characterizations. Hydrodynamic data will be obtained through review and processing of existing data and through additional data collection activities, as needed.

Clearly, existing data and previous studies provide a basis and starting point for the EIS hydrodynamic evaluation task. The EIS hydrodynamic evaluation includes the following components:

- Acquisition and review of available physical oceanographic data;
- Identification and collection of additional physical oceanographic data; and
- Compilation and processing of available and additional data into a common database with distribution to interested parties.

The hydrodynamic characterization of Long Island Sound, required to support consideration of potential open water disposal sites, will be developed through a synthesis of existing and additional data, and previously performed hydrodynamic characterizations. Important existing hydrodynamic characterizations include Sound-wide physical oceanography studies, hydrodynamic data collection programs, hydrodynamic modeling applications, and dredged material disposal and erosion studies. Dredged material disposal and erosion studies have been performed at existing disposal sites and generally consist of empirical evaluations focused on assessment of the fate and transport of dredged material. These previous studies provide critical contextual information to support the EIS hydrodynamic assessment.

The EIS hydrodynamic characterization may require additional hydrodynamic modeling to expand the usefulness of data and to provide technically-defensible hydrodynamic characterizations in support of potential disposal site designation. Two types of modeling applications may be required. First, a Sound-wide hydrodynamic modeling application may be required to provide a technically-defensible basis for selection of alternative disposal site areas. Second, to support detailed, site-specific hydrodynamic characterizations, a modeling application using the ADDAMS modeling suite with recent revisions or a similar modeling package will likely be required. The ongoing EIS hydrodynamic evaluation has been designed to support hydrodynamic modeling applications that may be required as the process moves forward.

Performance of the tasks listed above will enhance understanding of hydrodynamics in Long Island Sound and support the EIS process. The contents of this status report are outlined below. Section 2 contains a brief summary of hydrodynamics and sediments in Long Island. Section 3 contains a summary of existing hydrodynamic data and Section 4 contains a preliminary set of recommendations for additional data collection. This summary provides an update of project status and reference information to support evaluation of potential additional data collection and evaluation tasks.

2.0 OVERVIEW OF HYDRODYNAMICS AND SEDIMENTS IN LONG ISLAND SOUND

A brief overview of Long Island Sound hydrodynamics, sediment composition, and sediment transport is provided below.

2.1 HYDRODYNAMICS

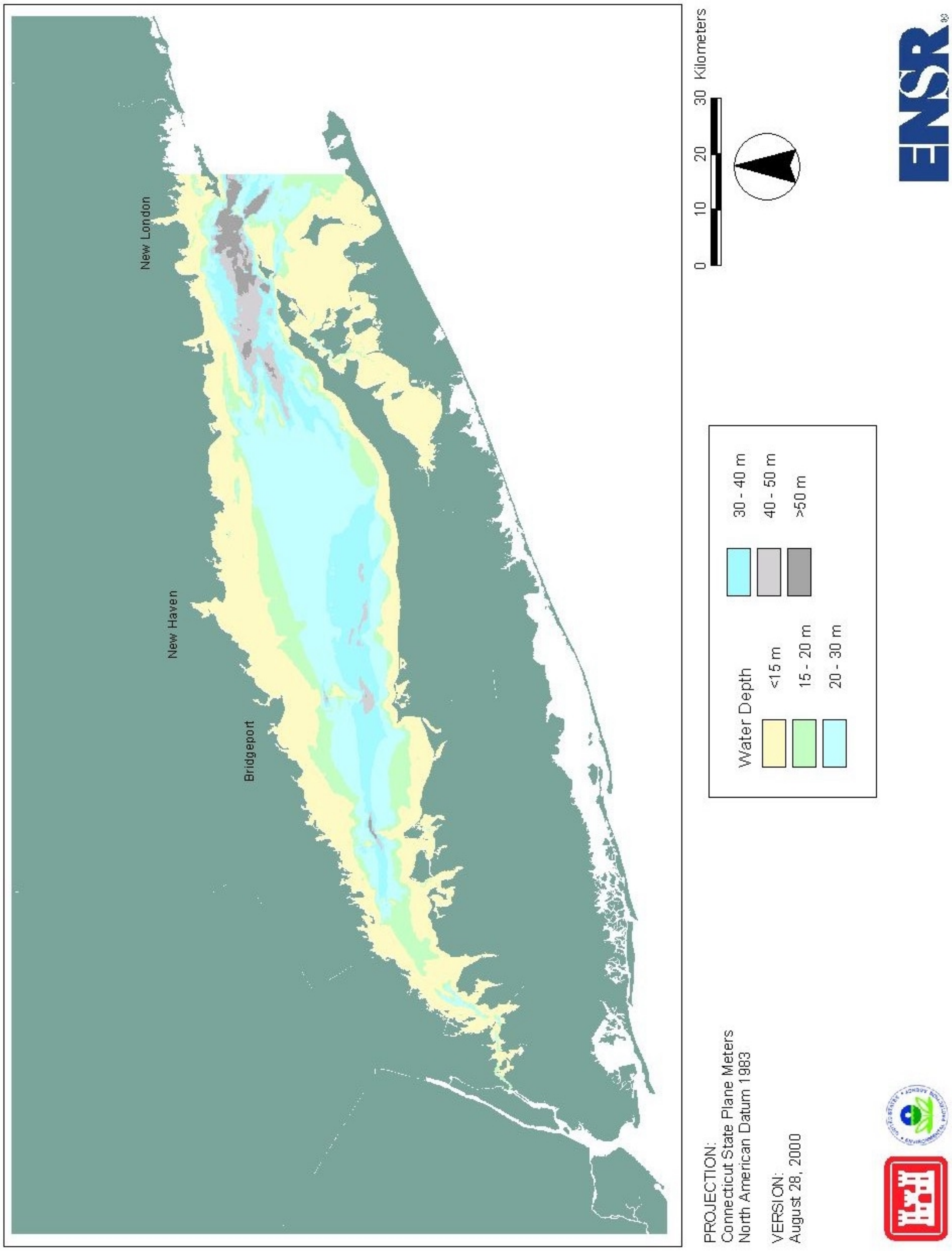
The hydrodynamics of Long Island Sound have been studied extensively through collection and analysis of field data and through mathematical modeling applications. Characterization of the currents and circulation patterns in the sound has provided an understanding of Sound-wide hydrodynamics and the observed sedimentary environments. A brief summary of general characteristics and previous hydrodynamic studies within the Sound is provided below.

Long Island Sound is approximately 90 miles long and 15 miles wide and oriented along a roughly east-west axis with open ocean exchange at eastern and western boundaries (Figure 1). The mean depth of the Sound is 20 meters and the maximum depth is 90 meters near its easterly boundary (Wolfe et al., 1991). Water movement in Long Island Sound is primarily driven by tidal forcings, with wind, storm events and freshwater inflows contributing to varying degrees. Storm events, producing wind-waves and establishing energetic flow regimes, combine with normal tidal forcings to create maximum water velocities and “worst-case” conditions in terms of potential dispersion of dredged material. Specifically, sustained storm events (e.g., 48 hours) featuring high winds along the axis of the Sound (i.e., roughly east-west) are expected to produce maximum bottom currents and potentially result in maximum sediment re-suspension in the Sound.

Water velocity magnitudes are observed to be greatest Eastern Long Island Sound and generally diminish with distance west. The amplitude of the M2 tide, the dominant tidal constituent, increases by a factor of 3 between the east and west end of the Sound, with similar decreases in water velocity indicating that the Sound is a resonant basin (Gordon, 1980). Tidal currents are generally oriented along the east-west axis of the Sound.

Although the Sound is not a typical estuary, with a river at the upstream end, well-developed estuarine circulation has been observed. In general, fresher, less dense water flows eastward along the surface, while saline water flows westward along the bottom of the Sound. There is a general counter-clockwise circulation in Long Island Sound, with currents along the north shore heading to the west and currents along the south shore heading east. There is also evidence for several localized gyres within the body of the Sound (Welsh, 1992)

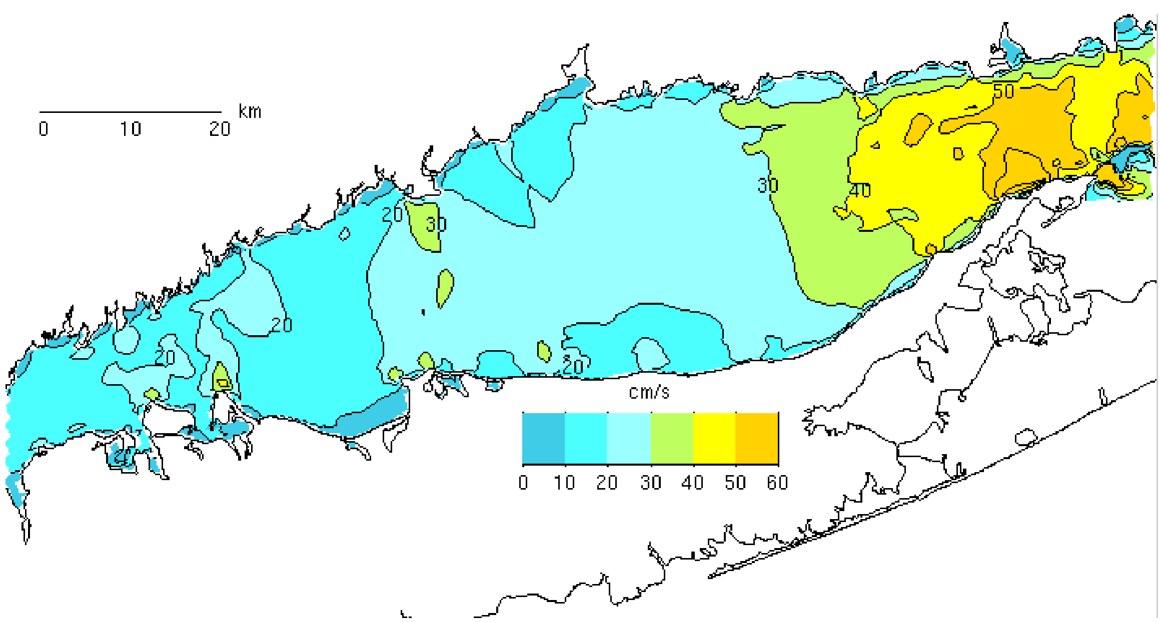
FIGURE 1   MAP OF LONG ISLAND SOUND WITH BATHYMETRY



Schmalz (1993) applied a three-dimensional hydrodynamic model to decompose the residual circulation into individual forcing components. He examined the relative effects of astronomical tide, density-driven currents, local wind driven currents and non-local shelf wind driven currents on the residual circulation patterns. Model simulations revealed the presence of counterclockwise gyres in the western and central basin, set up by the astronomical tide alone, and enhanced by the gravitational forcing due to density gradients. Near the surface of the water column, Schmalz found that forcing due to astronomical tide, density gradients and local wind were of the same order of magnitude, while the contribution of non-local shelf winds was an order of magnitude lower. Near the bottom of the water column, astronomical and density-driven forcings were slightly higher than local wind forcings, and non-local shelf winds had no effect on the predicted residual currents.

The U.S. Geological Survey set up a three-dimensional hydrodynamic model to predict bottom currents and to characterize the sedimentary environment of the Sound (Signell et al., 1997). The model included tidal and local wind forcings and assumed uniform density. The model predicted bottom currents 1 meter above the bottom throughout Long Island Sound (see Figure 2). The model predicted tidally-driven bottom currents of less than 20 cm/s in the western portion of the Sound, between 20-40 cm/s in the central Sound, 30-60 cm/s in the eastern Sound, and greater than 50 cm/s in the constriction at the eastern end of the Sound. Areas where the model predicted bottom currents greater than 30 cm/s corresponded to regions identified as erosional or non-depositional. In near-shore regions (water depth less than 20 m), wind-generated waves were found to contribute significantly to bottom orbital velocities and sediment transport.

FIGURE 2 PREDICTED BOTTOM CURRENTS AT 1 M ABOVE THE BOTTOM (FROM SIGNELL ET AL, 1997)



Vieira (2000) analyzed a series of velocity measurements to examine the long-term, residual circulation in the Sound. By filtering and averaging each data set, Vieira was able to describe residual flow patterns resulting from tidal and gravitational forcing, independent of time or specific events. Vieira observed denser, saline water entering the Sound from the east and flowing underneath outgoing, less saline water, indicative of classic estuarine circulation. In the Central Basin, he observed the incoming, saline water flowing through the deep, southern part of the sound, and the outgoing water flowing above it at lower speeds. In the Western Basin, outgoing flow is generally along the southern shore of the sound, and in the upper part of the water column, as the estuarine circulation is established. A counterclockwise gyre is discernable in the Western basin, consistent with the modeling results of Schmalz.

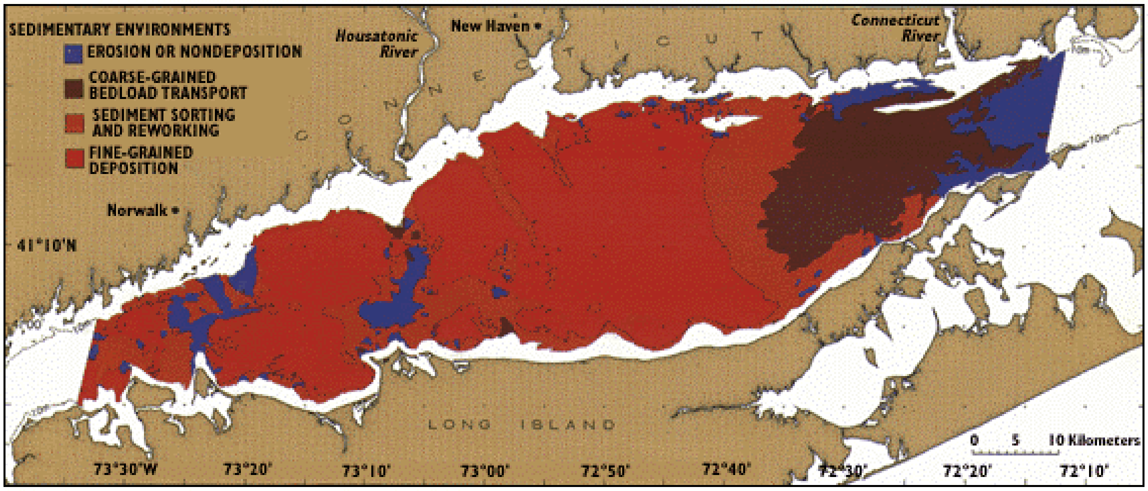
Kaputa and Olsen (2000) conducted a review of seven years of water quality data, primarily to understand the spatial and seasonal patterns of hypoxia in Long Island Sound. Time series measurements of temperature and salinity indicated a density stratification in the water column. The data revealed a strong temperature gradient, with warmer water above cooler bottom water. The temperature gradient was largest during June and early July, likely driven by warming air temperatures. Salinity gradients have also been observed, when saline water flows below fresher water, as previously described. These vertical density gradients lead to stratification in the water column, which contribute to the observed flow patterns in the Sound.

2.2 SEDIMENTARY ENVIRONMENT

The bottom sedimentary environment of Long Island Sound has been characterized by the U.S. Geological Survey, in cooperation with the Connecticut Department of Environmental Protection and the U.S. Environmental Protection Agency (Knebel, 1998). The sedimentary environment is indicative of the movement and deposition of sediments in the sound due to local and regional geologic and oceanographic conditions.

To characterize the sedimentary environment of Long Island Sound, the USGS conducted an extensive survey of the sea floor. Sidescan sonographs were collected and analyzed with the aid of sediment grab samples and video camera observations. Four long-term sedimentary environments were identified: erosion or non-deposition; coarse-grained bedload transport; sediment sorting and reworking; and fine-grained deposition (see Figure 3).

FIGURE 3   SEDIMENTARY ENVIRONMENTS ON LONG ISLAND SOUND (FROM KNEBEL, 1998)



At the eastern edge of the sound, extending approximately 5 to 8 km west, there is a large area of erosion or non-deposition, likely caused by combination of strong tidal currents and a net westward movement of sediments into the estuary (Knebel, 1998). West of this region is an area of coarse-grained bedload transport. This region extends approximately from the mouth of the Connecticut River westward 15 km, and is bordered on the western edge by a 5-km band of sediment sorting and reworking. The seafloor in this region is primarily sand, and transitions gradually to marine mud towards the central basin. The central and western basins of the sound are predominantly regions of fine-grained deposition. In localized areas, generally along north-south oriented shoals, there are regions of erosion or non-deposition and sediment sorting and reworking.

Turbidity measurements indicate that waves influence sediment transport around the margin of the Sound, up to depths of approximately 18 m (Bokuniewicz and Gordon, 1980). Within this margin, the bottom sediments are primarily sand, transitioning to mud with greater depths. In these deeper regions of the Sound, waves are expected to have little influence on sediments.

2.3 SEDIMENT TRANSPORT

The primary source of sediment entering the Long Island Sound is river inflow. Sediment loading from rivers varies greatly, with the majority being delivered during periods of storms and subsequent high discharge. Estimates of the load contributed by the Connecticut River (which contributes 71% of the total freshwater inflow) range from 0.8 x 10^8 kg/yr to 5 x 10^8 kg/yr (Bokuniewicz and Gordon, 1980). In general, sediment loading from rivers into the Sound is less than that of other estuaries, due to the erosion resistance of the glacial terrain that covers much of central New England (Gordon, 1980). Other sources of sediment include shoreline erosion and exchange with the continental shelf, both of which have not been well quantified, but are considered to contribute less than river inflow. Estimates of sediment supply into the Sound and sedimentation within the Sound are nearly equal, suggesting that the trapping efficiency of the Sound is nearly 100% (Gordon, 1980).

Sand transport (particle size >70 µm) covers approximately 44% of the floor of the Sound (Bokuniewicz, 1980). As mentioned above, the eastern portion of the Sound floor is covered by sand, transitioning westward to mud. The eastern edge of this transition zone is a north-south sand ridge called Mattituck Sill. The Sill is covered with sand waves, and sand movement occurs primarily as bedload transport. A net westward flux of sand has been calculated in this region, attributed to the superposition of the estuarine current on the tidal currents (Bokuniewicz, 1980). As the sand moves westward, it is immobilized by incorporation into the mud deposits that cover the central and western regions of the Sound.

The silt and clay particles that enter the sound are rapidly processed by benthic animals, which produce aggregate pellets (100 – 500 µm). The lack of individual particles with the Sound indicate that the rate of pellet production by the benthic community is large compared to the rate of sediment supply (Bokuniewicz and Gordon, 1980). A 10 mm layer of these pellets blanket the mud-dominated portions of the sea floor throughout the Sound. This layer can be re-suspended into the water column due to tidal excitation and storm events. Only during the largest storm events is the entire layer re-suspended. At the bottom of this layer, the pellets are converted into cohesive sediments, and are no longer subject to re-suspension. This mud, or permanent sediment, is estimated to accumulate at an approximate rate of 1 mm/yr. The production of new pellets maintains the approximately constant thickness of the upper, mobile layer of particles.

3.0 REVIEW OF AVAILABLE DATA

Prior to review of available data, data was obtained and compiled from various sources. Numerous organizations were contacted as part of this process including the Long Island Sound Study Program, the National Ocean Service (NOS), the USGS, US EPA, USACE, the City of New York, University of Connecticut, and State University of New York (SUNY) at Stony Brook. The following major Long Island Sound physical oceanographic data sets have been identified:

- NOS (1988-1990) throughout LIS
- SUNY (1989) throughout LIS
- City of New York (1995) Western LIS
- USACE (1997-1998) Eastern LIS
- UCONN (1980-present) throughout LIS

NOS, SUNY, and City of New York data sets have been obtained electronically and are summarized below. The USACE 1997-1998 data were collected at the New London disposal site are described in a draft report (SAIC, 1999) and will be obtained electronically in the near future. UCONN data were collected at numerous locations and will be obtained, if possible.

Other important hydrodynamic data on Long Island Sound have historically been collected. In particular, measurements were collected to support the previous disposal site selection and evaluation processes from the 1950s through 1980s (e.g., NUSC, 1979 and Nalwalk et al., 1973). In general, hydrodynamic data associated with these studies is not available electronically. Also, earlier studies resulted in relatively modest data sets compared to more recent surveys due to limitations in data collection technologies during those time periods. Some of these earlier studies featured data collection at existing disposal sites (e.g., USACE, 1985 and USACE, 1982) and are, therefore, useful to the present EIS process. These data will be presented and summarized as part of the hydrodynamic data review. Since these data are not available electronically, they will not be included in the Long Island Sound hydrodynamic database. It is recognized that other useful historic hydrodynamic data may exist. Additional historic data will be gratefully received and reviewed and will be included in the EIS hydrodynamic evaluation, if deemed appropriate.

Figure contains a map of Long Island Sound with existing hydrodynamic data collection locations, study sponsor, and sampling location number indicated. Seasons and durations of previously collected hydrodynamic data are provided in Table 1. Table 1 presents calendar time periods and durations for each data set with the year of data collection indicated in the left column. Long Island Sound regions are color-coded as indicated in the legend. Figure through Figure present data sets collected during each

FIGURE 4 COMPILATION OF HYDRODYNAMIC SAMPLING LOCATIONS IN LONG ISLAND SOUND

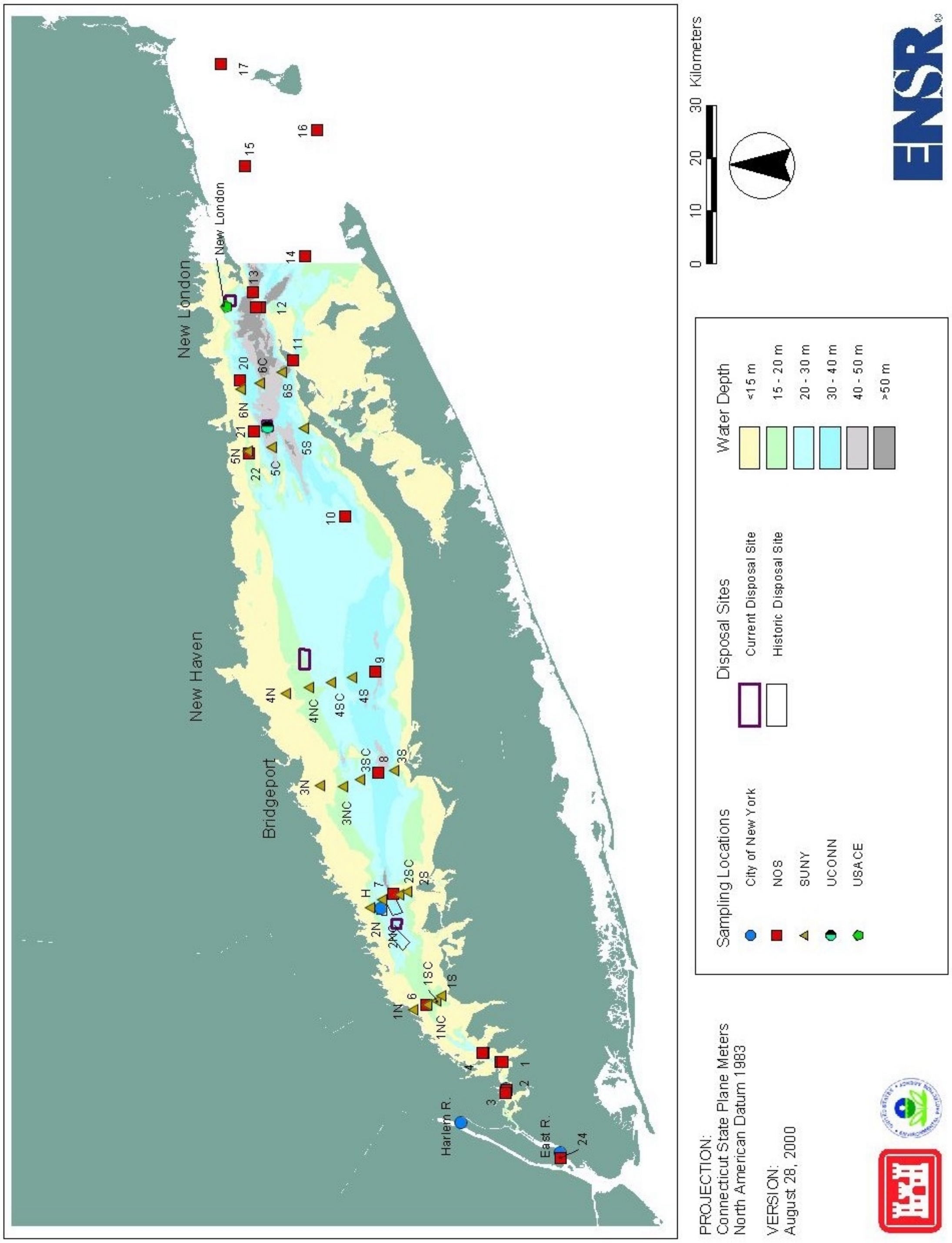


TABLE 1   SEASONAL HYDRODYNAMIC DATA COLLECTION SUMMARY

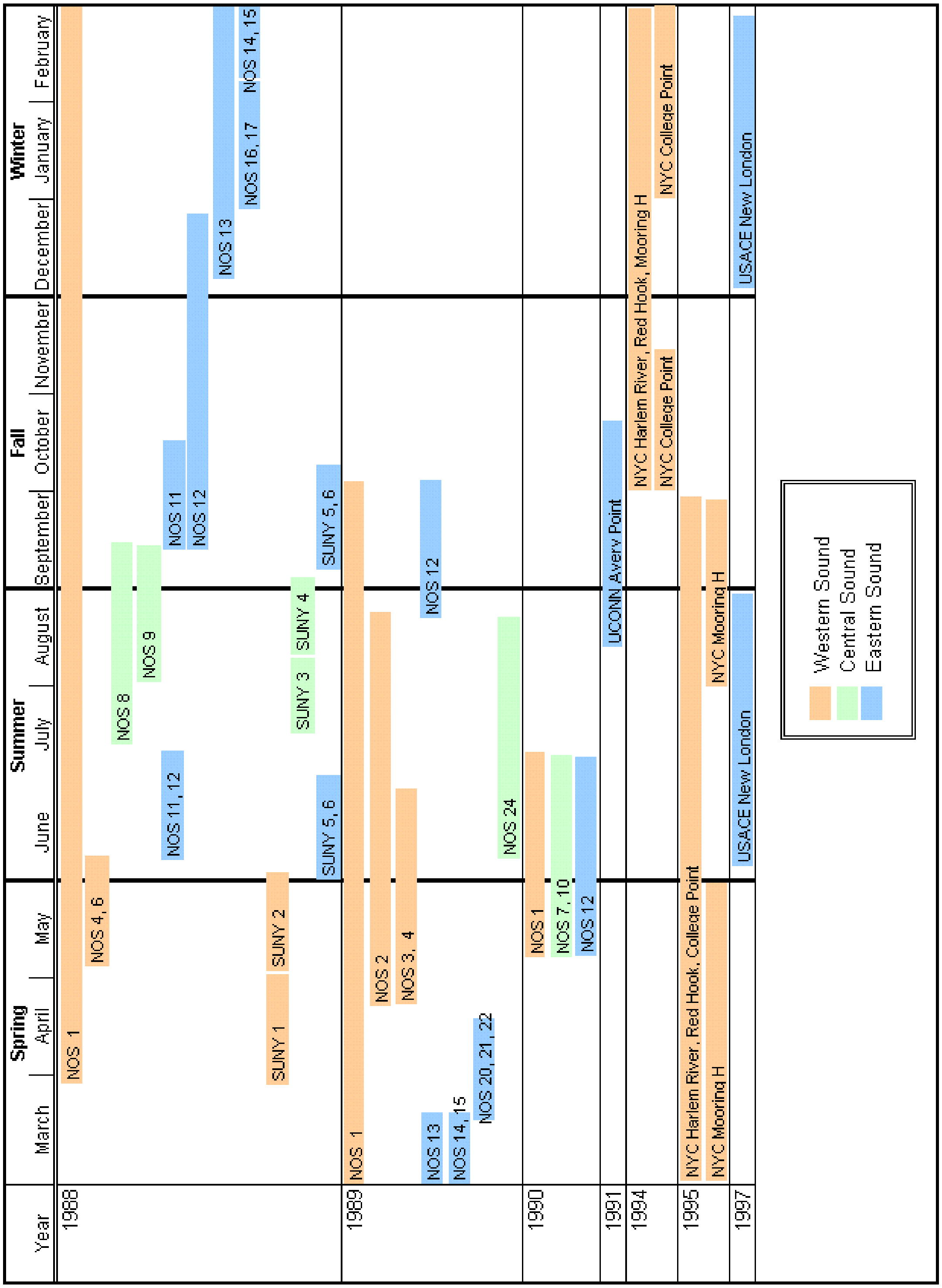


FIGURE 5 SPRING HYDRODYNAMIC SAMPLING LOCATIONS

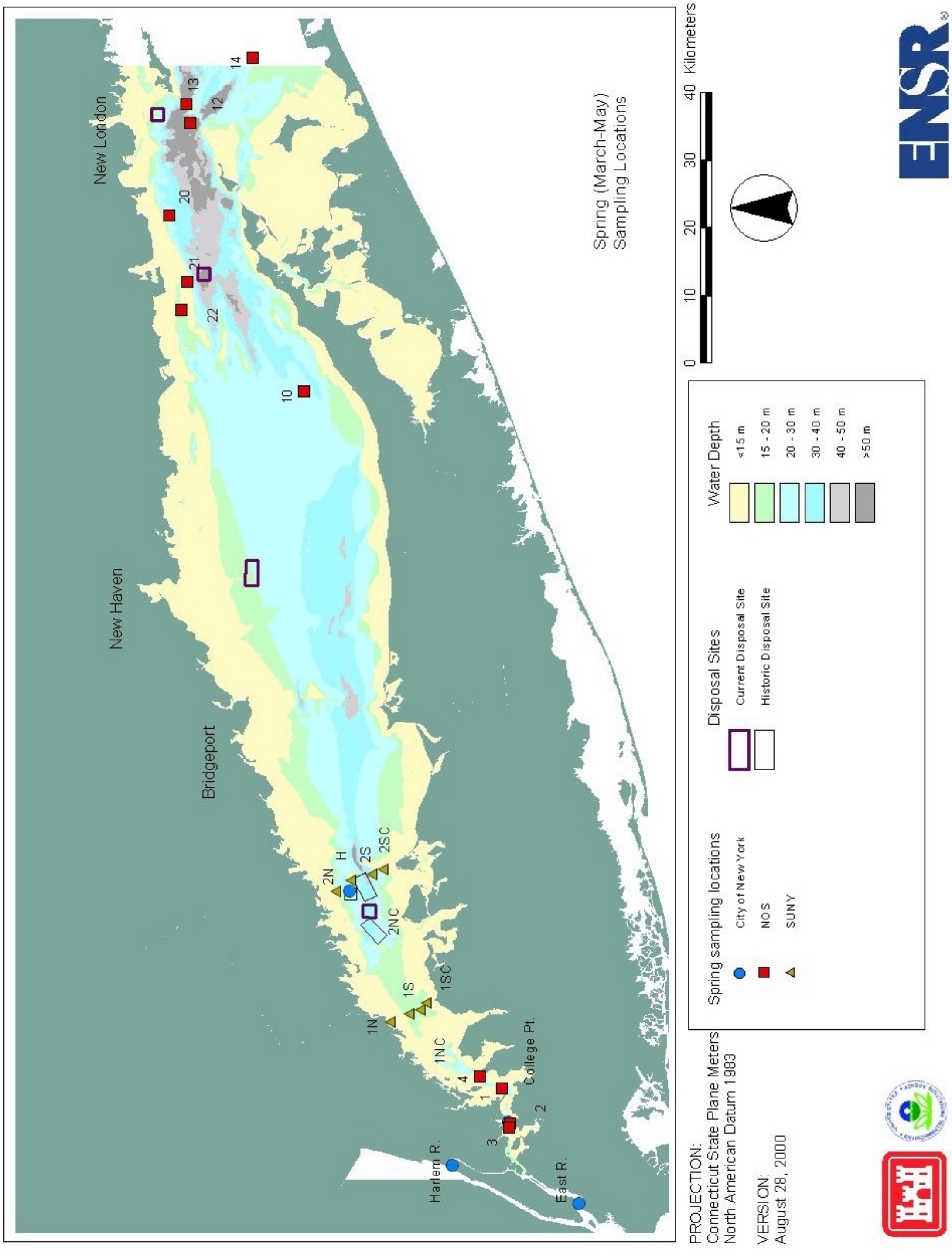


FIGURE 6   SUMMER HYDRODYNAMIC SAMPLING LOCATIONS

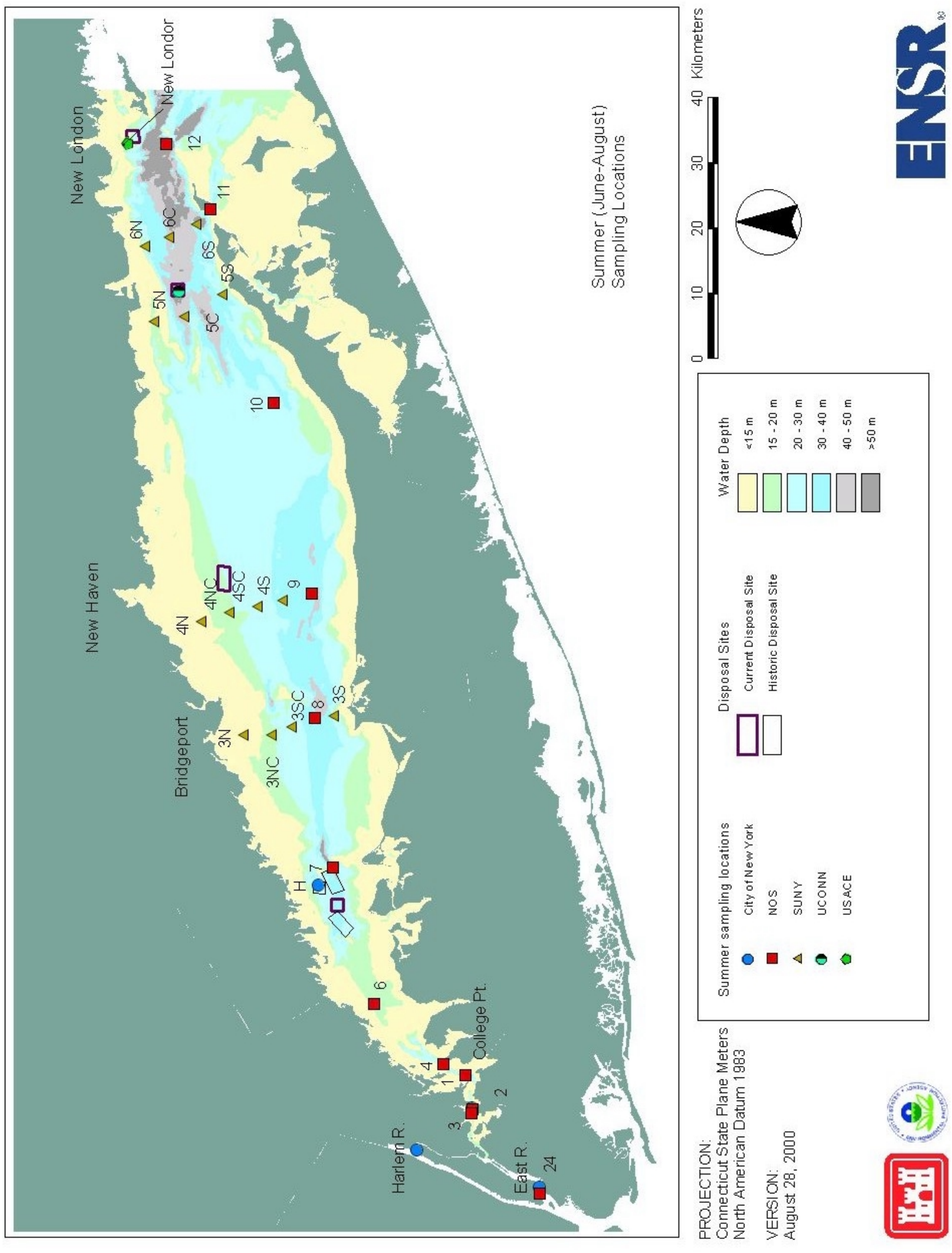


FIGURE 7 FALL HYDRODYNAMIC SAMPLING LOCATIONS

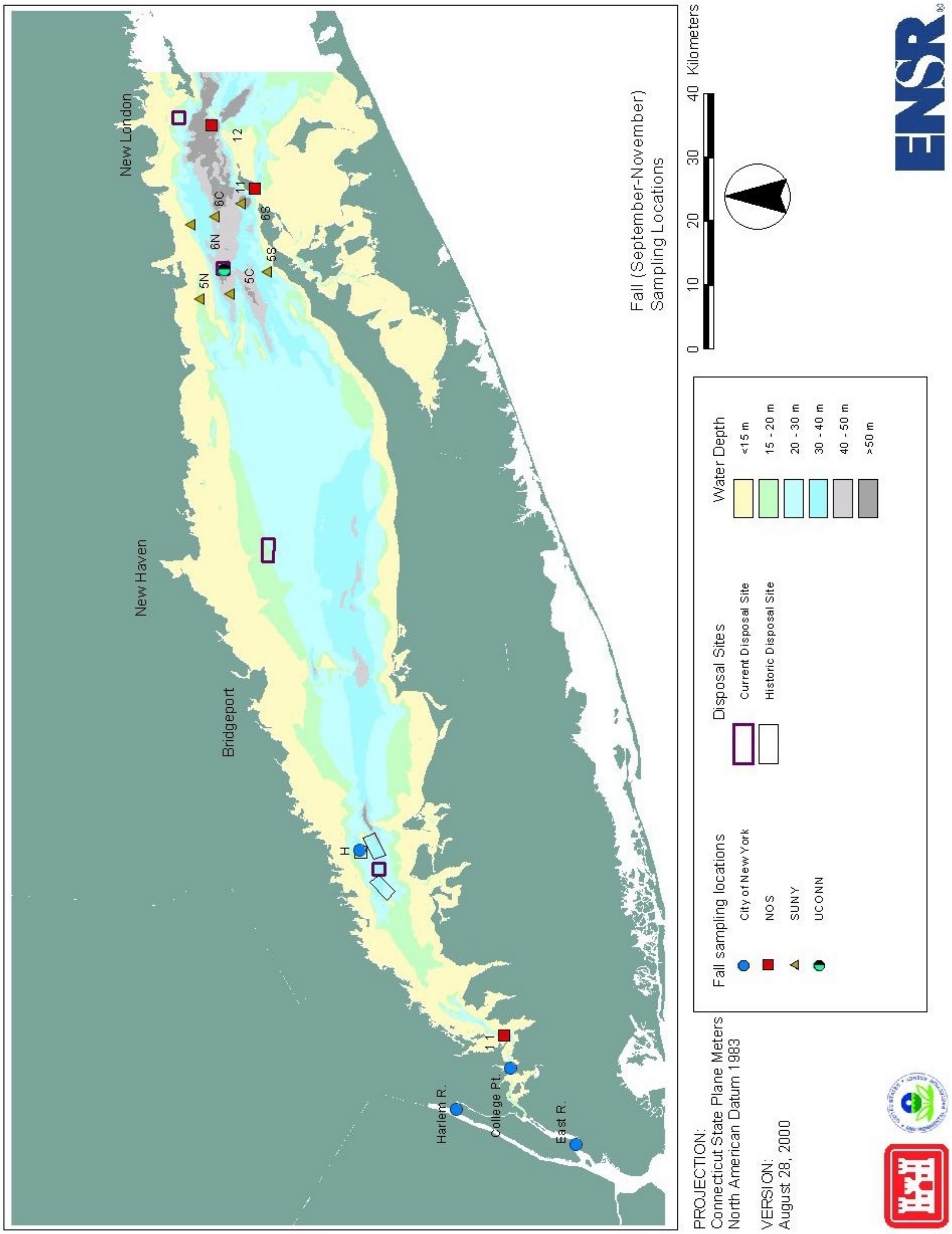
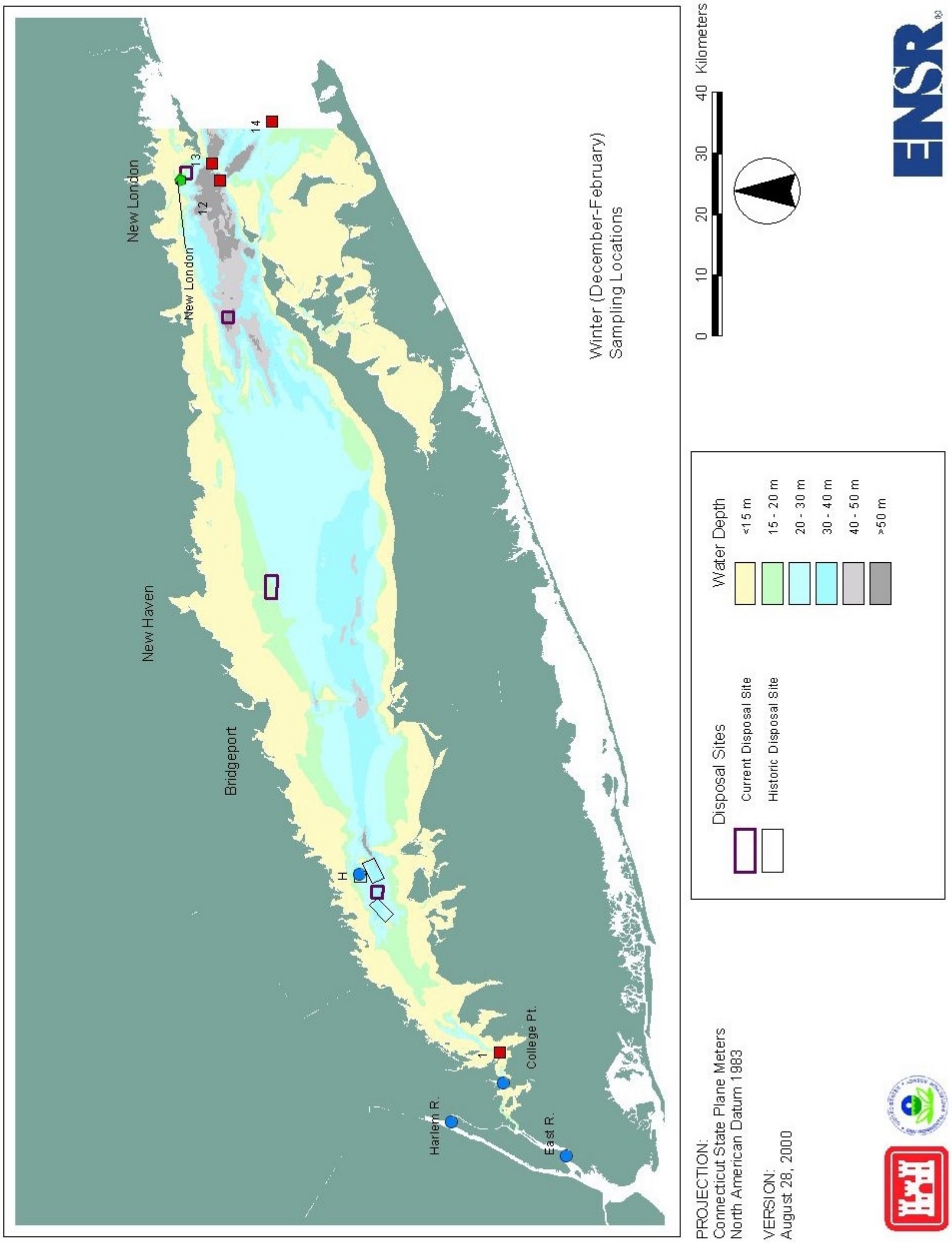


FIGURE 8 WINTER HYDRODYNAMIC SAMPLING LOCATIONS



season. Each of the data sets is summarized below. Following the summary of each data set, specific observations of data quality, spatial coverage, and seasonal coverage of the existing hydrodynamic data in Long Island Sound are summarized (Sections 3.6 - 3.9). Summaries of existing data in the Western, Central, and Eastern regions of Long Island Sound are also provided in Section 3.7.

3.1 NATIONAL OCEAN SERVICE (NOS) DATA

The U.S. EPA coordinated the multidisciplinary Long Island Sound Study (LISS) in order to support development of a comprehensive conservation management plan for Long Island Sound. The result of the study included the application of hydrodynamic and water quality models to explore circulation and transport processes, prediction of distribution of dissolved oxygen and nutrients in the Sound, and a set of recommended actions to improve water quality. The Estuarine and Ocean Physics Branch of NOAA's National Ocean Service (NOS) was tasked with acquisition of hydrodynamic data for the calibration and validation of the hydrodynamic model of Long Island Sound.

NOS conducted the Long Island Sound Oceanography Project (LISOP) from April 1988 to July 1990. Water velocity measurement locations are presented in Figure . All water velocity measurements were collected using acoustic Doppler current profilers (ADCPs) recording continuously and collecting measurements at one meter depth intervals throughout the water column. Table presents the dates of water velocity meter deployments. A project summary report (Earwaker, 1990) contains a complete description of LISOP data collection activities.

The LISOP program also featured collection of water level measurements at 18 locations around the shoreline of the Sound. Five of the locations support long-term water-level measurement stations. Measurements were recorded at the other 13 stations for periods of 0.25 to 12 months. Water elevations were measured with one of two types of pressure gauges: analog to digital recorder gage or nitrogen pressure driven bubbler gage. Tide staff gauges were also installed at each location, where observers recorded daily readings. No wave gauges were deployed as part of the LISOP program.

LISOP was conducted in three phases during 1988-1990 (Earwaker, 1990). Phases I and II were conducted from April 1988 to September 1999. Phase III was conducted from May to July 1990. The study area extended approximately 217 km, from the south entrance of the East River, through the East River and Long Island Sound to the outer boundaries of Block Island Sound. Table summarizes the surveys that were conducted during each phase.

FIGURE 9   NOS SAMPLING LOCATIONS

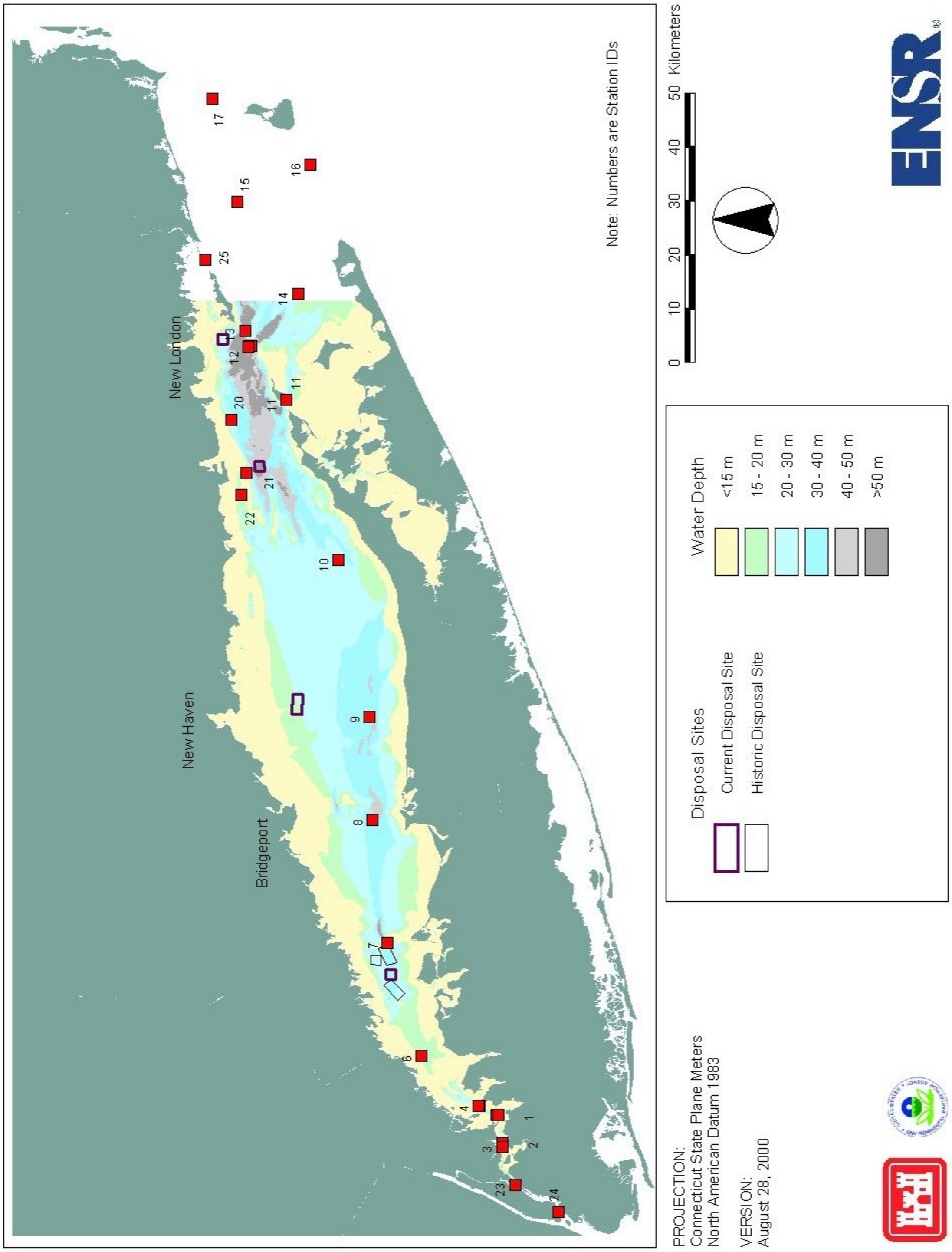


TABLE 2 DATES OF NOS DEPLOYMENTS

Station	Dates of Deployment
1	3/30/88-10/3/89*, 5/7/90-7/17/90
2	4/24/89-8/22/89
3	4/24/89-6/5/89
4	5/3/88-6/7/88, 4/24/89-6/5/89
6	5/3/88-6/7/88
7	5/7/90-7/17-90
8	7/14/88-9/13/88
9	8/2/88-9/13/88
10	5/6/90-7/18/90
11	6/9/88-7/13/88, 9/14/88-10/20/88
12	6/7/88-7/12/88. 9/14/88-12/29/88, 8/24/89-10/2/89, 5/6/90-7/18/90
13	12/7/88-3/14/89
14	2/10/89-3/16/89
15	2/10/89-3/15/89
16	12/30/88-2/8/89*
17	12/30/88-2/8/89*
20	3/17/89-4/20/89
21	3/17/89-4/20/89
22	3/17/89-4/20/89
24	6/6/89-8/22/89

*Record not inclusive for period

TABLE 3   SUMMARY OF NOS DATA COLLECTION ACTIVITIES

Survey	Phase I	Phase II	Phase III
Water level measurements	X	X	X
Current measurements	X	X	X
Conductivity and temperature time series		X	X
Conductivity and temperature vertical profiles			X

During Phases I and II of the project the following data was collected:

- Water levels at18 stations for durations of 0.25 to 27 months;
- Water velocity time series using bottom-based ADCPs at 18 stations for durations of 1.2 to 18 months;
- Water velocity transects using boat-based ADCPs featuring multiple runs along 6 transects;
- Conductivity and temperature time series at 2 stations for durations of 2.5 to 6 months; and
- Conductivity and temperature (CTD) profiles with multiple casts along 6 transects.

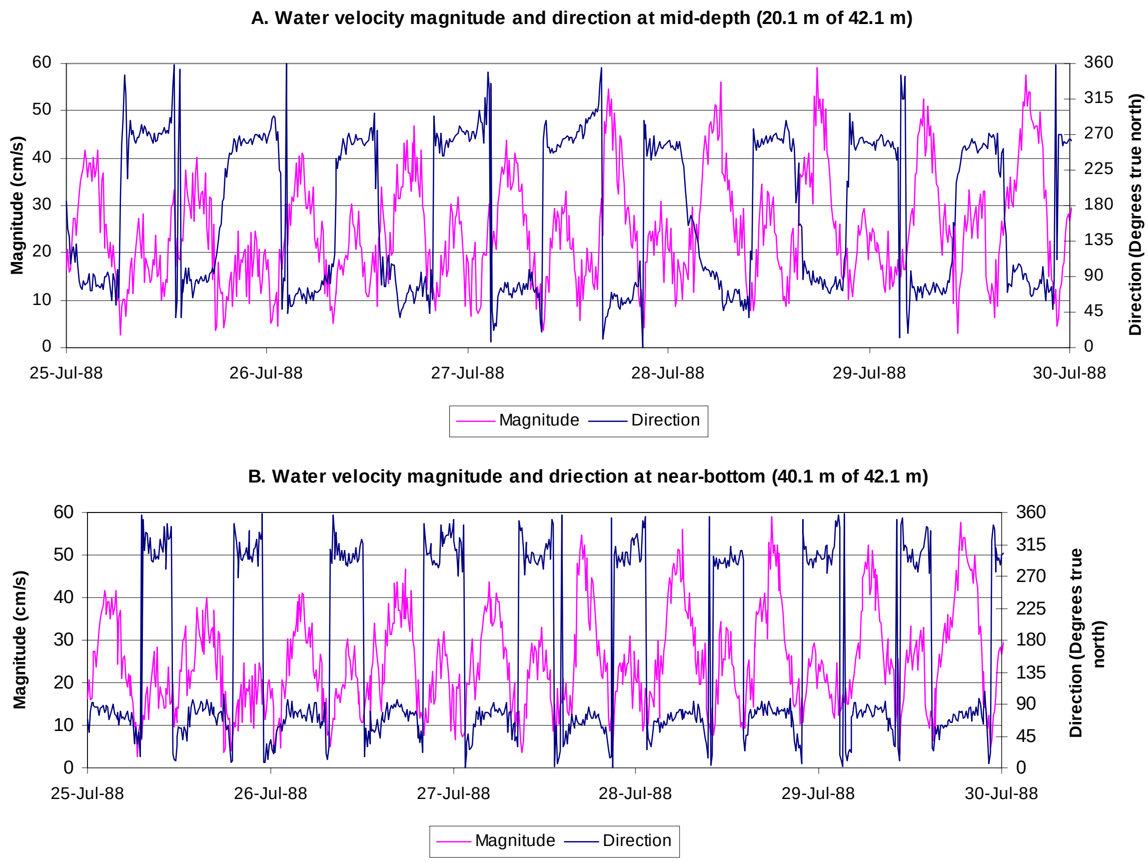
The following data was collected during Phase III of the project:

- Water levels at 10 stations for durations of 1.3 to 27 months;
- Water velocity time series at 4 stations for 2.5 months;
- Conductivity and temperature time series at 6 stations for 2.5 months; and
- Conductivity and temperature (CTD) profiles with multiple profiles at 15 stations.

In general, data recovery was excellent. Velocity data in two of the deployments (Stations 16 and 17) were lost for approximately one day due to power failures. Some of the 1989 conductivity/temperature time-series data at the Race Rocks station were also lost. All other data were successfully recovered.

To illustrate the data collected in this survey, data from Station 8 is presented in Figure . The figures present water velocity magnitude and direction for several days at the end of July 1988. The top figure presents the observed water velocity magnitude and direction at mid-depth. The bottom figure presents the observed water velocity magnitude and direction at a near-bottom location (2 meters above bottom). Water velocities measurements shown in Figure reach peak velocities of 60 cm/sec and flow directions are primarily northeast-southwest, aligned with tidally induced flows in the Sound. Overall, the NOS data set was found to be of high quality and provides the largest set of existing hydrodynamic data.

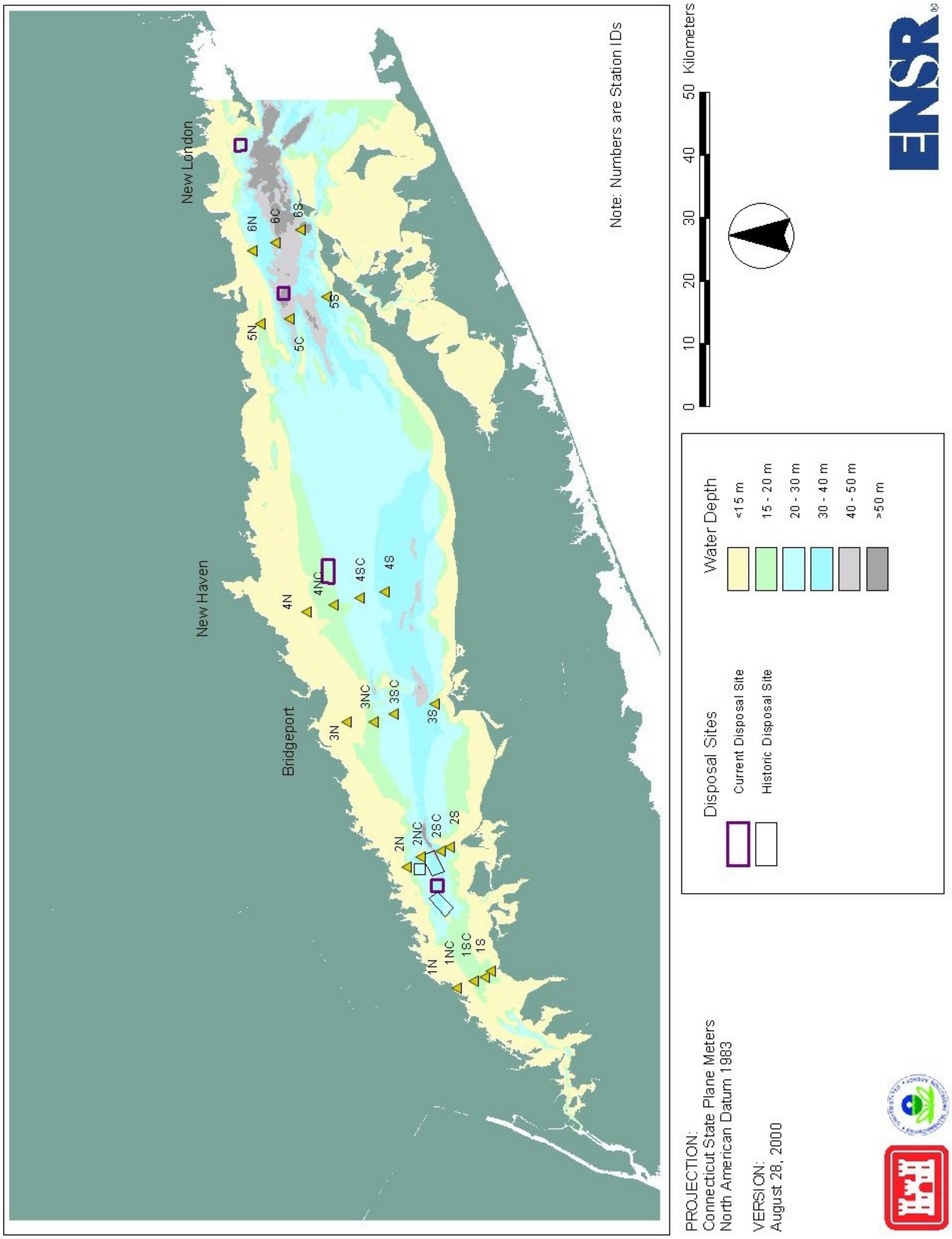
FIGURE 10   WATER VELOCITY MEASUREMENTS AT NOS STATION 8



3.2 STATE UNIVERSITY OF NEW YORK (SUNY) STONY BROOK DATA

The Marine Sciences Research Center of the State University of New York (SUNY), Stony Brook, collected current data between March and October 1988 in support of the EPA-sponsored Long Island Sound Study. The objective of the field program was to collect a hydrodynamic data set to complement the NOS data set and to support three-dimensional hydrodynamic model development and application. SUNY data was collected along 6 transects throughout Long Island Sound at locations indicated in Figure . Water velocity measurements were collected using an array of fixed-point sensors. At each transect, four vertical arrays of 2 to 4 instruments were moored across the sound, with the uppermost instrument at least 2 m below the water surface.

FIGURE 11 LOCATION OF SUNY TRANSECTS



Instruments were moored along each transect for approximately one month, at which time they were removed and re-deployed at the next transect. Only transects 5 and 6 were occupied simultaneously during the deployment period. Thus, the ability to compare measurements collected from different transects is reduced because they were collected non-concurrently. No tide gauges or wave gauges were deployed as part of the SUNY program.

The data collected in this study is presented in a comprehensive report (Vieira, 1990) including comments on the quality and completeness of each data record and plots and summary statistics of the velocity, temperature and salinity time series data. Although each of the instruments was treated with anti-fouling paint, many of the water velocity and conductivity sensors were subject to biological fouling, particularly during the summer months. This led to erroneous data, including damped velocity measurements towards the end of the period of record or, in some cases, little or no usable data retrieval. Table summarizes the effective recovery of the SUNY velocity data.

TABLE 4 SUMMARY OF SUNY VELOCITY DATA RECOVERY

Transect	Dates	No. of Instruments	Complete Velocity Records	Partial Velocity Records
1	3/28/88-5/2/88	14	8	5
2	5/2/88-6/1/88	10	7	2
3	7/14/88-8/9/88	11	5	6
4	8/10/88-9/7/88	13	5	8
5	6/1/88-7/5/88	7	3	1
	9/8/88-10/14/88	8	3	4
6	6/1/88-7/5/88	7	4	2
	9/8/88-10/14/88	9	7	1

Despite the fairly high incidence of biological fouling of the instrumentation, the collection effort provided useful data to support characterization of circulation in the Sound. A summary and interpretation of the data is presented in Vieira (2000) and discussed in Section 2.1.

3.3 CITY OF NEW YORK

The City of New York sponsored an extensive data collection program in New York Bight, New York Harbor and Long Island Sound to provide calibration and validation data for a system-wide eutrophication model. A water quality model was developed to explore treatment options for sewage effluent as part of a treatment facility upgrade. The field program comprised five tasks: water column monitoring, point source sample analysis, sediment flux and pore water analysis, hydrodynamic monitoring and atmospheric measurements.

The hydrodynamic monitoring program was conducted by Batelle Ocean Sciences from October 1994 to October 1995 (Fredriksson and Dragos, 1996) and included data collection at locations shown in Figure . Instrument suites were deployed for a period of one year and included water velocity meters, tide pressure gauges and conductivity/temperature gauges. Within Long Island Sound, four current meters, one tide gauge and two conductivity/temperature gauges were deployed (Table). Bottom-based ADCP instruments were deployed at three location; at Red Hook, College Point, and at Harlem River. At location H, two current meters were deployed at 3 m and 25 m in 29 meters of water.

Data recovery for the City of New York instrumentation in Long Island Sound was generally good. The Harlem River current meter, Red Hook current meter and the conductivity/temperature gauge at location G all had 100% recovery. Significant corrosion of the College Point current meter resulted in two months of data loss (November and December). Intermittent power failures resulted in some gaps (during June and July) in the data collected at location H. The data is summarized and presented in a summary report (Fredriksson and Dragos, 1996).

A single tide gauge was deployed in Long Island Sound, at the west end at the mouth of the Harlem River. Measurements were made using a SeaBird SeaGage pressure sensor. Data collected at this location included sub-surface pressure, barometric pressure, temperature and conductivity. The instrument was deployed from November 1994 to November 1995, with 100% data recovery. No wave data was collected as part of the City of New York program.

3.4 UNITED STATES ARMY CORPS OF ENGINEERS DATA

The USACE New England District DAMOS program sponsored a hydrodynamic data collection program in within the New London Disposal Site in Eastern Long Island Sound in 1997 and 1998 (SAIC, 1999). The investigation was conducted by Science Applications International Corporation (SAIC) and included bottom-based ADCP current profiles, near-bottom current measurements, tide and wave measurements, and boat-based synoptic ADCP current measurement surveys.

Recording hydrodynamic instruments were deployed in the northwest corner of the New London Disposal Site and collected measurements from September 19 to October 30, 1997 and from January 22 to February 27 1998. Both deployments featured collection of near-bottom water velocity measurements and wave measurements. The winter 1998 deployment included collection of bottom-based ADCP current measurements and collection of synoptic boat-based ADCP current measurements. Maximum water velocities of 85 cm/sec at near surface and 55 cm/sec at near bottom locations were measured

FIGURE 12   CITY OF NEW YORK MEASUREMENT LOCATIONS

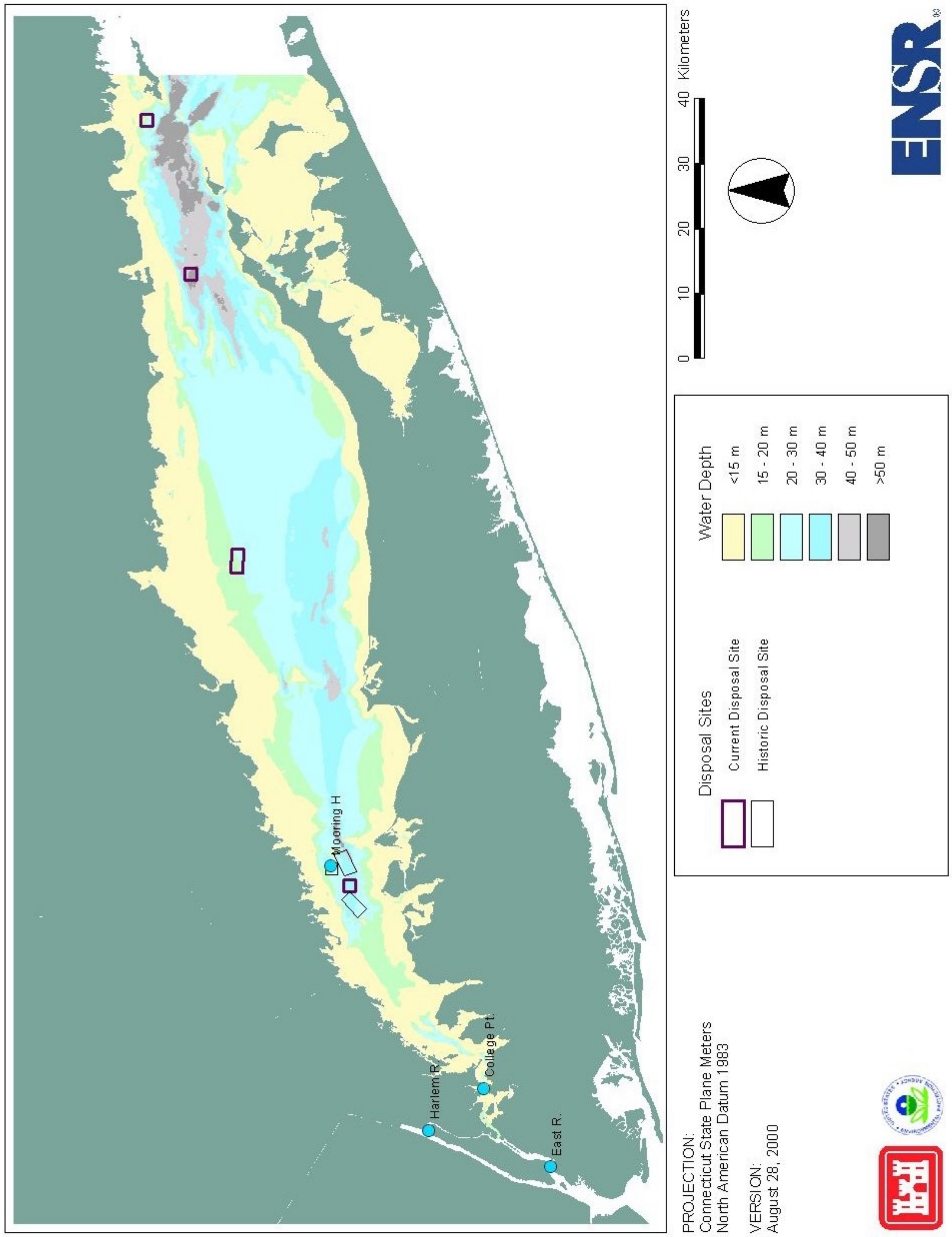


TABLE 5 SUMMARY OF CITY OF NEW YORK METER DEPLOYMENTS

Location	Current Meter	Conductivity/Temperature Meter	Water Level
Harlem River	**X**[1]		
Harlem River Tide			**X**
Red Hook	**X**[1]		
College Point	**X**[1]		
Location G		**X**	
Location H	**X**[2]	**X**	

Notes: 1 Profile measurements

2 Near-surface and near-bottom measurements

during the winter 1998 survey in the New London disposal site. The 1997/1998 USACE/SAIC New London Disposal Site data set provides the most useful hydrodynamic data collected within an existing disposal area.

3.5 UNIVERSITY OF CONNECTICUT (UCONN), AVERY POINT DATA

Investigators from the University of Connecticut have conducted a number of hydrodynamic data collection programs in Long Island Sound. Some of these programs were focused on collection of hydrodynamic data at existing disposal sites (Bohlen, 1992). These data represent important contributions to the body of existing hydrodynamic data in Long Island Sound and are should be included in the set of data presented in the EIS. To date, ENSR has been unable to obtain existing hydrodynamic data from investigators from the University of Connecticut.

In 1991, hydrodynamic data was collected by UCONN within the Cornfield Shoals Disposal Site (USACE, 1996). Measurements were collected from mid-depth and near-bottom using fixed-point water velocity sensors. The mid-depth sensor was deployed from August to October 1991 and the near-bottom sensor was deployed from July to October of 1991.

Between 1980 and 1990, UCONN deployed near-bottom water velocity meters at disposal sites in Western, Central, and Eastern Long Island Sound (Bohlen, 1992). These deployments resulted in collection of near-bottom water velocity data (at one meter above the sea floor) in each of three disposal sites. UCONN has recently and is currently collecting bottom-based ADCP measurements at various locations Long Island Sound (Kay Howard-Strobel, personnel correspondence).

3.6 DATA QUALITY SUMMARY

The NOS data set is by far the most extensive hydrodynamic data set available in the Long Island Sound region. Quality of the NOS data set was found to be generally very good and the durations of deployments typically include several tidal regimes. SUNY data was found to be of marginal quality. Large periods of recorded data are degraded by biofouling and several meters failed to collect measurement of extended periods (i.e., more than a few days). Thus, the SUNY data set appears, based on review of data coverage maps, such as Figure , to provide a more extensive data set than it actually does. The City of New York data was found to be of generally good quality and provides a solid contribution to the Western Long Island Sound region data set via the Location H data collection site. The USACE data have not been reviewed, but are believed to be of good quality and to provide a strong contribution to Eastern Long Island Sound region data set at the New London Disposal Site.

Of the major water velocity data sets, only the USACE (1997-1998) data set included concurrent wave data collection. Wave data is important in that it enables investigators to measure the effects of wave energy on near-bottom (and potentially, water-column) water velocities. The usefulness of the NOS, SUNY, UCONN, and City of New York data is diminished by the lack of concurrent wave measurements.

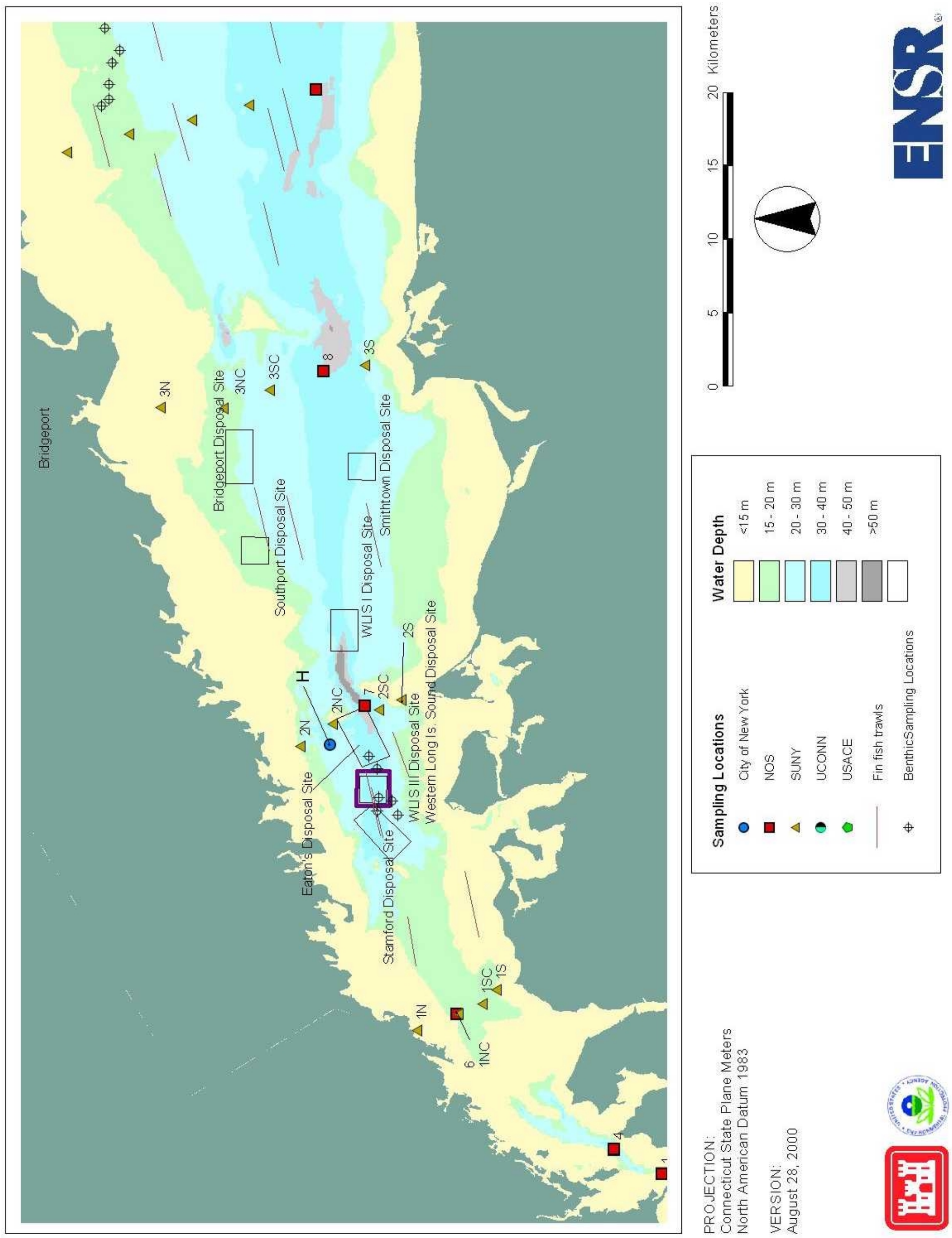
3.7 SPATIAL COVERAGE SUMMARY

Existing Long Island Sound hydrodynamic data has primarily been collected at the eastern and western boundaries of the system. This is due to the objectives of previous studies. For example, studies performed in support of hydrodynamic modeling require strong data sets at model boundaries (e.g., the eastern and western boundary of LIS). As a result, the best characterized areas of the Sound, in terms of both the number and quality of data collection activities, are near the Race and near the East River. Hydrodynamic data collected at these locations is not ideally suited to support EIS hydrodynamic characterizations. A summary of hydrodynamic data collection in each basin of Long Island Sound is provided below.

3.7.1 Western Long Island Sound Coverage

Figure 13 contains a map of Western Long Island Sound with locations of previous sampling activities indicated. Of existing data, the most directly applicable data appear to be City of New York data collected at Location H and NOS data at locations 6, 7, and 8. The City of New York data was collected for a period of one year using near-surface and near-bottom water velocity meters (at 4 meters above bottom) located approximately 3 kilometers northeast of the Western Long Island Sound disposal site. NOS data at locations 6, 7, and 8 were collected during late spring and summer seasons when worst-case storm conditions are least likely to occur. SUNY data collected along transect #2 during the spring season are also available. Sparse data are available at or near the WLIS disposal sites. In the late 1970’s and early

FIGURE 13 MAP OF WESTERN LONG ISLAND SOUND WITH PREVIOUS SAMPLING LOCATIONS INDICATED



1980's, limited data were collected at several disposal sites in Western Long Island Sound (USACE, 1982). These data are of limited utility due the quality of the instrumentation and the brevity of deployments. The extent and quality of previously collected WLIS hydrodynamic data is likely not sufficient to support the present EIS process.

3.7.2 Central Long Island Sound Coverage

Figure 14 contains a map of Central Long Island Sound with locations of previous sampling activities indicated. A paucity of data has been collected in the Central LIS region. In total, sampling was performed at SUNY transect #4 and NOS locations 9 and 10 within this area. Both the SUNY and NOS data collection activities in Central Long Island Sound were performed during the summer season when worst-case storm events are least likely to occur. The Central LIS region is large and potentially well-suited for disposal site designation. Thus, it is unfortunate that so little data is available in this region.

Relatively little hydrodynamic data has been collected in Central Long Island Sound compared to the Eastern and Western regions. No recent and available hydrodynamic data have been collected in Central Long Island Sound during the fall, winter, or spring season. Existing data does not provide good spatial coverage of the Central region. For example, there is no available hydrodynamic data over the entire width of the Sound between the CLIS disposal site and Long Sand Shoal, except for at NOS location 10. Thus, over an area of approximately 1200 km^2 (40km by 30km) only one data set is available to support hydrodynamic characterization. Sparse data are available at or near the CLIS disposal site. In the late 1970's and early 1980's, limited data were collected at CLIS (USACE, 1985). These data are of limited utility due the quality of the instrumentation and brevity of the deployments. The extent and quality of previously collected CLIS hydrodynamic data is likely not sufficient to support the present EIS process.

3.7.3 Eastern Long Island Sound Coverage

Figure 15 contains a map of Eastern Long Island Sound with locations of previous sampling activities indicated. Hydrodynamics have been relatively well characterized in Eastern Long Island Sound compared to the Central and Western regions. Six NOS sampling locations, six SUNY sampling locations, one USACE sampling location, and UCONN sampling locations have been situated in the Eastern Long Island Sound region.

Hydrodynamic measurements have been collected at the New London Disposal Site and at the Cornfield Shoals Disposal Site in the 1990's (USACE 1997-1998 and UCONN 1991). Of existing data, the USACE data in the New London Disposal Site is most useful because it was collected during the winter season and included wave and near-bottom water velocity measurements. The existing New London and Cornfield Shoals Disposal Site data sets may be sufficient to support the present EIS process.

FIGURE 14 MAP OF CENTRAL LONG ISLAND SOUND WITH PREVIOUS SAMPLING LOCATIONS INDICATED

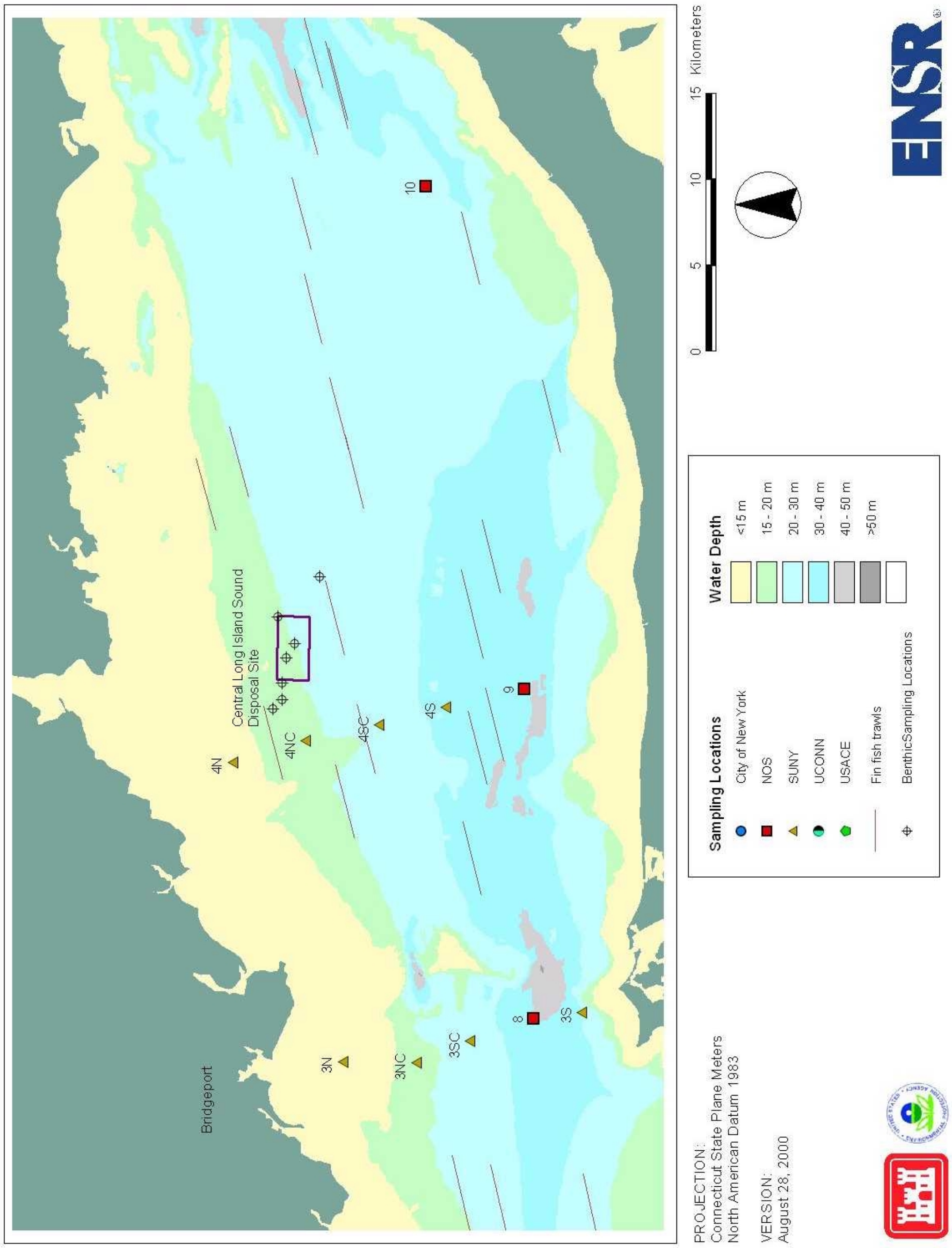
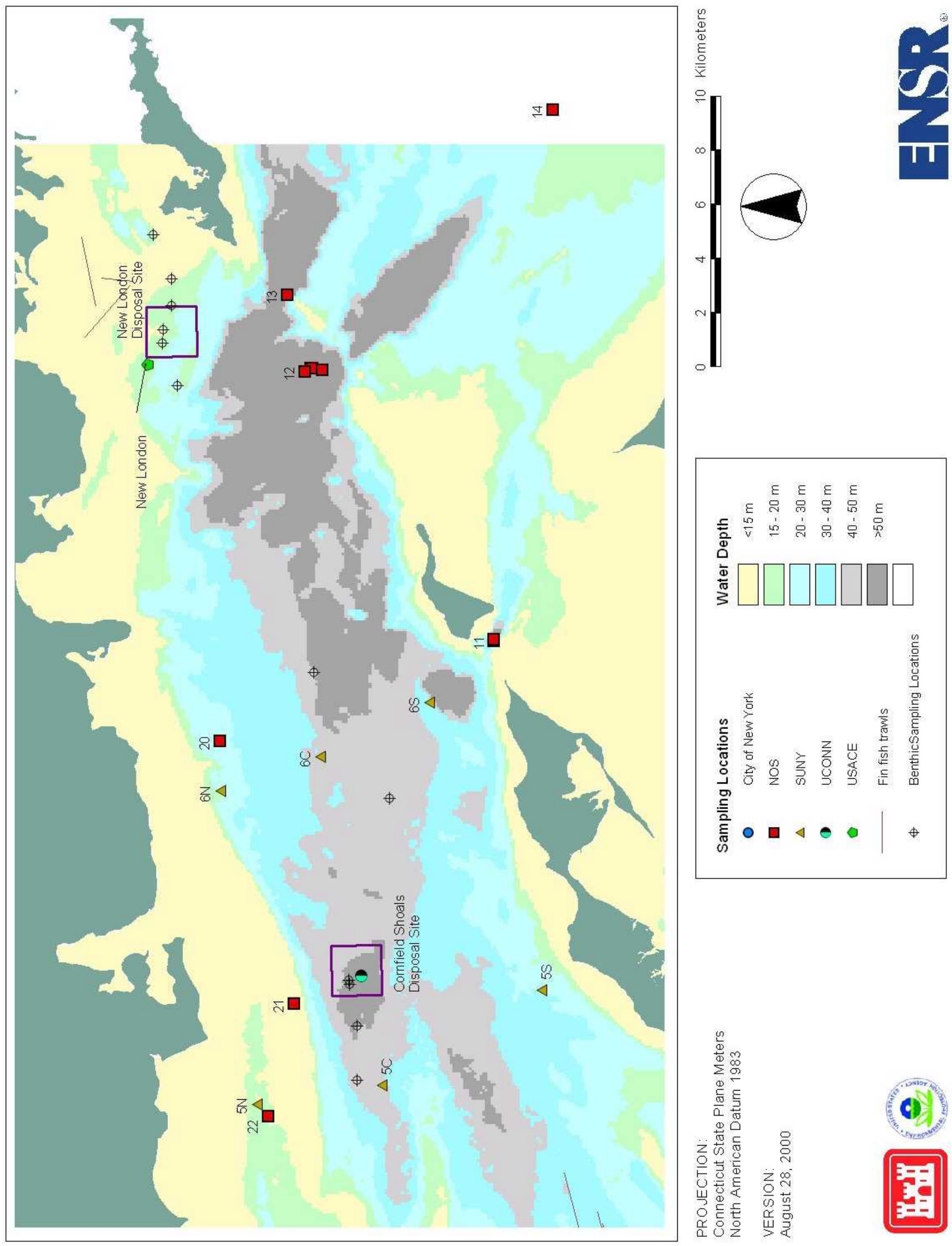


FIGURE 15 MAP OF EASTERN LONG ISLAND SOUND WITH PREVIOUS SAMPLING LOCATIONS INDICATED



Relatively strong currents throughout most of the eastern region have been well documented. Strong currents in Eastern LIS are credited with creating a non-depositional sedimentary environment throughout most of the region. Thus, most of the Eastern LIS region is likely not suitable for designation of disposal sites due to unfavorable hydrodynamic conditions.

3.8 SEASONAL COVERAGE SUMMARY

Hydrodynamic data collected during the fall, winter, and spring season are most useful to support the EIS evaluation because “worst-case” storm events tend to occur during these seasons (see Section 4.2). As shown in Figure 7, relatively little data have been collected during the fall, winter, and spring seasons in Long Island Sound. No data have been collected in the Central region and only the Location H data (City of New York, 1995) has been collected in the Western region. SUNY and NOS data were collected in the Eastern region during the fall season, but are not near the existing disposal area. USACE data collected at the NLDS are most useful for characterizing the fall/winter hydrodynamic characteristics of the Eastern region.

The largest seasonal data set was collected during the summer (Figure). In general, data from this season is least useful to support the EIS because disposal events generally do not occur during the summer season when “worst-case” hydrodynamic conditions are least likely to occur.

The occurrence of storm events during deployments effects the usefulness of the data collected. Specifically, data collected during “worst-case” storm events is highly valuable to the present EIS process. For all major existing data sets, available wind and wave height data will be obtained and reviewed for the historic deployment periods to provide storm event context. Storm event contextual information will support a more detailed characterization of the existing data set relative to the requirements of the present EIS.

3.9 SUMMARY

Existing hydrodynamic data in Long Island Sound is well-suited to support Sound-wide hydrodynamic characterizations and modeling applications. In general, the existing data set is not as well-suited to support the EIS hydrodynamic evaluation. Major data gaps identified in the review of existing data include the following:

- Little data collection activities focused on measurement of hydrodynamic conditions during storm events in the Sound;
- Little wave data collected along with current measurements;

- Little data collected concurrently at different locations to support spatial characterization and comparison of hydrodynamic conditions.
- Little data collected in the Central Basin region in general and no recent data collected in the Central region during non-summer seasons; and
- Little data collected at the Western LIS and Central LIS Disposal Site;

Additional data collection activities should address the data gaps identified above.

4.0 PRELIMINARY RECOMMENDATIONS FOR ADDITIONAL DATA COLLECTION

4.1 APPROACH TO SAMPLING LOCATION SELECTION

Additional data collection recommendations will be identified based on data gaps in existing hydrodynamic data in Long Island Sound and on data collection requirements of the EIS process. Data gaps have been identified and are documented above. Data collection requirements of the EIS process, however, have not yet been specified. In particular, new (as opposed to existing) alternative open water disposal sites have not yet been identified.

A site screening process is presently underway throughout the entire Sound to support identification of potentially suitable open water disposal sites. This site screening process requires consideration of numerous factors, including hydrodynamic, ecological, and economic characteristics, in order to support consideration of potentially suitable sites for designation. The hydrodynamic characterization is a component of this site screening process and is dependent on these related and concurrent assessments. Thus, selection of hydrodynamic sampling locations is, in part, dependent on the suitability of sampling locations from other perspectives (e.g., potential for benthic community impacts and/or proximity to a major harbor). In the coming months, all of the factors affecting open water disposal site screening will be evaluated.

Given this project status, it is recommended that specification of additional data collection activities be determined in the coming months, as other important information affecting the site screening process becomes available. Additional data collection activities will likely be recommended within Western, Central, and Eastern Long Island Sound. In each area, broad regions may be selected as potentially suitable based on hydrodynamic factors such as the expected magnitude of near-bottom currents and water depth. Other factors including the locations of existing hydrodynamic data, locations of existing disposal areas, and sediment composition will also be considered in selecting additional data collection areas. In general, since existing disposal areas are potential sites for designation, hydrodynamic characterization at these locations is recommended (e.g., within the CLIS disposal site in the Central region).

Recommended hydrodynamic data collection activities will likely be focused primarily on obtaining data necessary to support hydrodynamic characterization within existing disposal areas and at potentially suitable alternative locations in the Sound. These data collection activities will support comparison of the hydrodynamic suitability of existing sites vs. potential alternative sites within the same region. Prior to finalizing data collection recommendations, additional input and guidance will be obtained to ensure that best available information and judgement is incorporated into the sampling program design.

4.2 DATA COLLECTION PROGRAM DESIGN

Ideally, sampling would take place during worst-case conditions in terms of potential for dispersion of dredged material such as during disposal events and during storm events resulting in sediment scour. In Long Island Sound, worst-case conditions tend to occur during sustained storm events, particularly storms featuring high winds along the axis of the Sound. Such storms are most likely to occur during the fall through spring periods. In addition, dredged material disposal events typically occur from September to May in Long Island Sound. Thus, it is recommended that additional data collection activities be performed during the fall, winter, and/or spring periods. A deployment period of one to two months is recommended to capture tidal variations and to increase the potential for capturing worst-case storm event conditions.

Characterization of near-bottom water velocities is of critical importance to the data collection program. Water-column water velocity measurements, wave measurements, and tidal elevation measurements are also important. At each sampling location, a hydrodynamic data collection instrument suite containing the following instruments is recommended:

- Water velocity meters at near-bottom locations (e.g., using fixed-point acoustic velocity sensors located between 0.5 and 2 meters above bottom);
- Bottom-based ADCPs to conduct water column water velocity measurements;
- Wave gauge to measure waves and to measure the wave-induced components of water velocities;
- Tide gauge to measure water elevation; and
- Boat-based synoptic ADCP surveys along transects spanning fixed sampling locations to expand the spatial dimension of the hydrodynamic assessments.

Recommended quantity and locations of hydrodynamic data collection suites will be determined in the coming months based on additional review of hydrodynamic characteristics and on other related factors (e.g., ecological and economic factors).

5.0 BIBLIOGRAPHY

Bokuniewicz, H.J. 1980. Sand Transport at the Floor of Long Island Sound. *Advances in Geophysics*. 22:107-128.

Bokuniewicz, H.J. and R.B. Gordon. 1980a. Storm and Tidal Energy in Long Island Sound. *Advances in Geophysics*. 22:41-67.

Bokuniewicz, H.J. and R.B. Gordon. 1980b. Sediment Transport and Deposition in Long Island Sound. *Advances in Geophysics*. 22:69-106.

Bohlen, F.W. 1992. Fine Grained Sediment Transport in Long Island Sound: Transport Modeling Considerations. Long Island Sound Research Conference Proceedings. Southern Connecticut State University. October 23-24, 1992. New Haven, CT.

Dragos, P. 1995. Final Work/Quality Assurance Project Plan (W/QAPP) for New York City Newtown Creek Facilities Upgrade Planning Project. Prepared by Battelle Ocean Sciences, Duxbury, MA. Prepared for Greeley and Hansen Engineers, Philadelphia, PA.

Earwaker, K.L. 1993. Long Island Sound Oceanographic Project: Data Inventory. Coastal and Estuarine Oceanographic Branch, National Ocean Service.

Earwaker, K.L., ed. 1990. Long Island Sound Oceanographic Project: 1988-1990. NOS Oceanographic Circulation Survey Report No. 10. US Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, MD.

ENSR. 1988. Long Island Sound Connecticut and New York, Dredged Material Disposal Site Evaluation Report. Prepared for US Army Corps of Engineers, New England Division.

Fredriksson, D.W. and P. Dragos. 1996. Hydrodynamic Measurements in the New York Bight, New York Harbor, and Long Island Sound: Final Data Report for October 1994 to October 1995. Prepared by Battelle Ocean Sciences, Duxbury, MA. Prepared for Greeley and Hansen Engineers, Philadelphia, PA.

Gordon, R.B. 1980. The Sedimentary System of Long Island Sound. *Advances in Geophysics.* 22:1-40.

Kaputa, N.P. and C.B. Olsen. 2000. Long Island Sound Summer Hypoxia Survey 1991-1998 Data Review. Prepared by Bureau of Water Management, Planning and Standards Division, Connecticut Department of Environmental Protection. Prepared for US Environmental Agency and Long Island Sound Study.

Knebel, H.J. 1998. Sedimentary Environments in Long Island Sound: A Guide to Sea-Floor Management in a Large Urbanized Estuary. USGS Fact Sheet FS 041-98. US Geological Survey, Woods Hole Field Center, Woods Hole, MA.

Nalwalk, A.J., D.F. Paskausky, W.F. Bohlen, and, D. Murphy. 1973. New Haven Dump Site Seabed and Surface Drifter Study, University of Connecticut, Avery Point, Groton, CT.

NUSC. 1979. DAMOS: Disposal Area Monitoring System Annual Data Report – 1978. Naval Underwater Systems Center, Newport, RI. Submitted to New England Division, Corps of Engineers, Waltham, MA.

Riley, G.A. 1952. Hydrography of the Long Island and Block Island Sounds. *Bulletin of the Bingham Oceanographic Collection*. 13:5-39.

SAIC. 1999. Observations of Physical Oceanographic Conditions at the New London Disposal Site, 1997-1998: Draft. Science Applications International Corporation, Newport, RI. Prepared for New England District, U.S. Army Corps of Engineers, Concord, MA.

Schmalz, R.A. Jr. 1993. Numerical Decomposition of Eulerian Residual Circulation in Long Island Sound, Proceedings, *In* Third International Conference on Estuarine and Coastal Modeling, ASCE Press, p. 294-308.

Signell, R.P. H.J. Knebel, J.H. List and A.S. Farris. 1997. Physical Processes Affecting the Sedimentary Environments of Long Island Sound. *In* 4th International Conference on Estuarine and Coastal Modeling, M.L. Spaulding and A.F. Blumberg, eds. ASCE Press.

Swanson, R.L., C.A. Parker, M.C. Meyer, and M.A. Champ. 1982. Is the East River, New York, a River of Long Island an Island? NOAA Technical Report NOS 93. US Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, MD.

USACE. 1982. Final Environmental Impact Statement for the Designation of a Disposal Site for Dredged Material in Western Long Island Sound WLIS III. US Army Corps of Engineers, New England Division.

USACE. 1985. DAMOS: Disposal Area Monitoring System: Overview of a Program. US Army Corps of Engineers. Waltham, MA.

USACE. 1996. DAMOS: Disposal Area Monitoring System: Synthesis of Monitoring at the Cornfield Shoals Disposal Site, July 1991 to May 1992. Contribution 105. January 1996. US Army Corps of Engineers, New England Division, Waltham, MA.

Vieira, M.E.C. 1990. Observations of Currents, Temperature and Salinity in Long Island Sound, 1988. A Data Report. Marine Science Research Center, State University of New York, Stony Brook, NY. Special Sata Report #6, Reference #90-13.

Vieira, M.E.C. 2000. The Long-Term Residual Circulation in Long Island Sound. *Estuaries.* 23(2):199-207.

Welsh, B.L. 1992. Physical Oceanography of Long Island Sound: an Ecological Perspective. Long Island Sound Research Conference Proceedings, Southern Connecticut State University, October 23-24, 1992. New Haven, CT.

Wolfe, D.A., R. Monahan, P.E. Stacey, D.R.G. Farrow, A. Robertson. 1991. Environmental Quality of Long Island Sound: Assessment and Management Issues. *Estuaries,* 14(3):224-236.